The A. & M. College of Texas

DEPARTMENT OF OCEANOGRAPHY

PROGRESS REPORT FOR PERIOD

1 June 1953 to 30 April 1954

Navy Department
Office of Naval Research
Contract N7 onr-487 T.O. 3

Project NR 083-061
Third Annual Report
June 1954

Research Conducted through the

Texas A. & M. Research Foundation

COLLEGE STATION, TEXAS
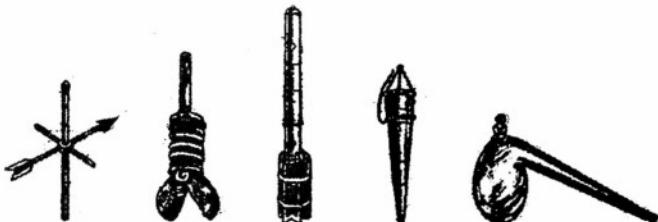
The Agricultural and Mechanical College of Texas
Department of Oceanography
College Station, Texas

Texas A & M Research Foundation
A&M Project 29 - Reference 54-39F

REPORT FOR CONTRACT PERIOD

1 JUNE 1953 to 30 APRIL 1954

Project 29 is a study of the atmospheric influence
on the thermal structure of the oceans, sponsored
by the Office of Naval Research (Project NR 083-061,
Contract N7onr-487, Task Order 3).

Report Prepared June 1954

by

Carter R. Sparger

Dale F. Leipper - Project Supervisor

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ANNUAL REPORT

Project 29

INTRODUCTION

This is the final report to be issued under contract N7onr-487 T.O. 3
which was concluded 30 April 1954, and serves as the third annual report
issued under that task order. Unfinished work will be continued under
contract N7onr-487 T.O. 2.

An attempt is made here to present in some order the basic concepts
which have led to the studies conducted by this project, and to provide
continuity between them. A list of the present staff and staff changes
during the past year, biographies and a list of technical reports issued
under Task Order 3 conclude the report.

The section entitled "Ocean-Wide Heat Transport" was written by
Mr. G. H. Jung. Mr. Jung and Mr. R. A. Gilcrest aided Mr. C. R. Sparger
in preparing the rest of the report. Editing was done by Dr. John Freeman
and Dr. Dale F. Leipper.

DISCUSSION

The General Problem

Specifically, the purpose of this project is to study the atmospheric
influence on the thermal structure of the sea. For practical purposes, in
deep water, all thermal structure changes are directly due to meteorologi-
cal and astronomical influences. The influx of water from the continents
and the exchange of heat between the sea and its solid boundaries are
negligible.

In some particular region of the sea, the total amount of heat
present will, in general, change as a result of heat-exchange with the air
above it. This will be accompanied by local thermodynamic affects. The
distribution of heat will be affected further by the dynamic effects of
semi-permanent currents, local winds, distant storms and the movement of
the moon and sun with respect to the earth. In what way are each of these
influences felt and to what degree?

Data

Through the cooperation of Woods Hole Oceanographic Institution and
Scripps Institution of Oceanography it has been possible for this project
to obtain on loan, and to microfilm, all bathythermograph data gathered
between 1945 and 1950 by weather ships in the Atlantic Ocean and between
1943 and 1952 in the Pacific. Stations occupied by these ships have been
in relatively deep water. All completed studies of this project have been
based on this vast amount of data--over 55,000 observations in all.

Though abundant, these data have not been entirely satisfactory.
The ships have been too few and stationed too far apart to allow picturing
realistically the temperature structure of the entire ocean at a given

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time. In all studies completed to date, it has been found necessary to treat each station individually.

Supplementary BT observations have been taken aboard the Texas A and M Research Foundation vessel, A. A. Jakkula, in the Gulf of Mexico. Two week-long cruises, one in October 1953 and the other in April 1954, have been devoted primarily to taking BT and associated meteorological observations. These data will be issued as a technical report during the coming year.

To make BT data available in an easily usable form while at sea on such cruises, an instrument has been constructed which photographs and rapidly prints a BT trace superimposed on an appropriate temperature vs. depth grid. A Polaroid Land camera is used. The instrument is modeled after that described in Report 417* of the U.S. Naval Electronics Laboratory, San Diego, California.

Processing Data

There are six weather ship stations in the Atlantic Ocean, and there have been, from time to time, 32 in the Pacific. The processing routine employed in handling data from these ships is described in Technical Report No. 1 of this project, issued in 1952. As noted in that report, a "typical" BT is chosen for analysis from among those taken on a given day. The criterion of choice is that the observation be made nearest the time of day during which, over all, most BTs were taken. Exceptions to this rule are made when such BTs differ radically from others taken the same day.

Using "typical" BTs, five-day mean vertical thermal structures are obtained for each day for which sufficient data exists. The procedure of

* Schaniel, Carl L. "A Copy Camera for Rapid Reproduction of Bathythermograph Information", Sept. 1953.

neglecting exceptional traces and averaging has been established in an effort to eleminate from the data the effects of "internal waves".

The energy associated with any disturbance of the ocean, whatever its cause, is propagated outward from its source until either dissipated by viscosity or lost against some land mass. The passage of such energy is manifest in isothermal-surface waves in the sea as well as in waves along the air-water interface. The former are generally believed to be larger than the later in relation to the small density differences within the water as compared with that between air and water. Thus, internal waves may be of considerable amplitude. The bulk of data possessed by this project is not well suited to take these phenomena accurately into account.

Neglecting exceptional traces and averaging tends to eliminate the affect on the thermal structure of astronomical tides and to subdue the effects, say, of distant storms which influence the thermal structure on a single day. Locally-caused, transient effects, both dynamic and thermal, are subdued also. But there are net effects due to local winds, radiation, evaporation, etc., that appear to be retained in the data and to be related to the average of each of these quantities. It is assumed that tides and distant storms have no such net effect and may therefore be neglected in subsequent analysis.

That a five-day period is the best over which to average cannot be completely justified. But longer periods would be unsatisfactory because of time-gaps in the data, and results obtained using 5-day means have been promising.

Data processed as described are said to be "smoothed". Smoothed data for all six Atlantic stations have been issued as Technical Report

No. 3 of this project. Smoothed data for 12 Pacific stations have been published as Technical Report No. 7.

Indices of Heat-Content and Heat Distribution

It has been found convenient to treat the heat-content change represented by the difference between two smoothed BTs taken at the same position in terms of the area between the traces when superimposed on an appropriate temperature vs. depth grid. This quantity, A_T, the total heat change, has the units $\frac{\text{foot-degrees}}{L^2 \text{ week}}$, where L^2 represents a surface area of any size over which all variables are essentially constant.

Most BTs taken by weather ships reach only to a depth of about 450 feet. Week-to-week changes in heat content, even as given by smoothed data, occur below that depth. The method adopted in estimating heat changes in deep water is discussed in detail in Technical Report No. 4. The method is based on the assumption that temperature at a given station is constant below 656 feet.

However, by far the largest week-to-week change takes place in a surface layer which varies in depth from generally shallow in summer to generally deep in winter. Within this layer the water is isothermal or very nearly so. Below is a layer of large temperature gradient. Below about 600 feet, the water is again isothermal.*

The depth of the upper isothermal layer (H)--the mixed layer depth or depth of the thermocline--is the quantity most frequently used as an index to the heat distribution. It is often used alone in this regard.

Evaluating H is a more or less subjective process. It is sometimes chosen simply as the depth at which the top-most "appreciable" change in

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* Even deeper, a layer of especially large gradient, sometimes called the the permanent thermocline, is often found. This project has confined its attention to the upper or seasonal thermocline.

temperature gradient occurs.

To avoid this subjectivity and yet comply with the meaning intended, the following definition has been proposed: A thermocline is a layer of the sea in which the temperature gradient equals or exceeds the gradient that would exist were temperature a linear function of depth between the surface and 600 feet. On a temperature vs. depth grid, thermocline boundaries occur where lines parallel to the reference gradient are tangent to the observed trace. The upper surface of the upper thermocline is the mixed layer depth, H. (See Fig. 1)

These concepts will be discussed more fully in a later report. It is sufficient to say here that the definition is simple to apply and serves to introduce another variable, the reference gradient, that, with H, better defines the distribution of heat.

Practical Time-Relations between Heat-Content and Distribution

A. Total Heat Change

Let Q be the heat content, expressed in foot-degrees*, of some unit volume in the sea at the initial moment. If the sea is motionless, Q changes appreciably only under the influence of solar radiation, back radiation and evaporation:

$$(1) \quad \frac{\partial Q}{\partial t} = f_1(A_S) + f_2(A_B) + f_3(A_E)$$

where A_S, A_B and A_E are heat fluxes across the air-sea interface due to these factors. $\frac{\partial Q}{\partial t}$ varies with each in a manner depending on the position of the unit volume with respect to the interface.

In order that the system remain vertically motionless, the combined effect of the terms on the right must be constant or decrease with depth.

* The amount of heat needed to raise the temperature $1^\circ F$ of a volume of water 1 foot deep which has a cross-sectional area over which the vertical flux is essentially constant.

Temperature (°F)
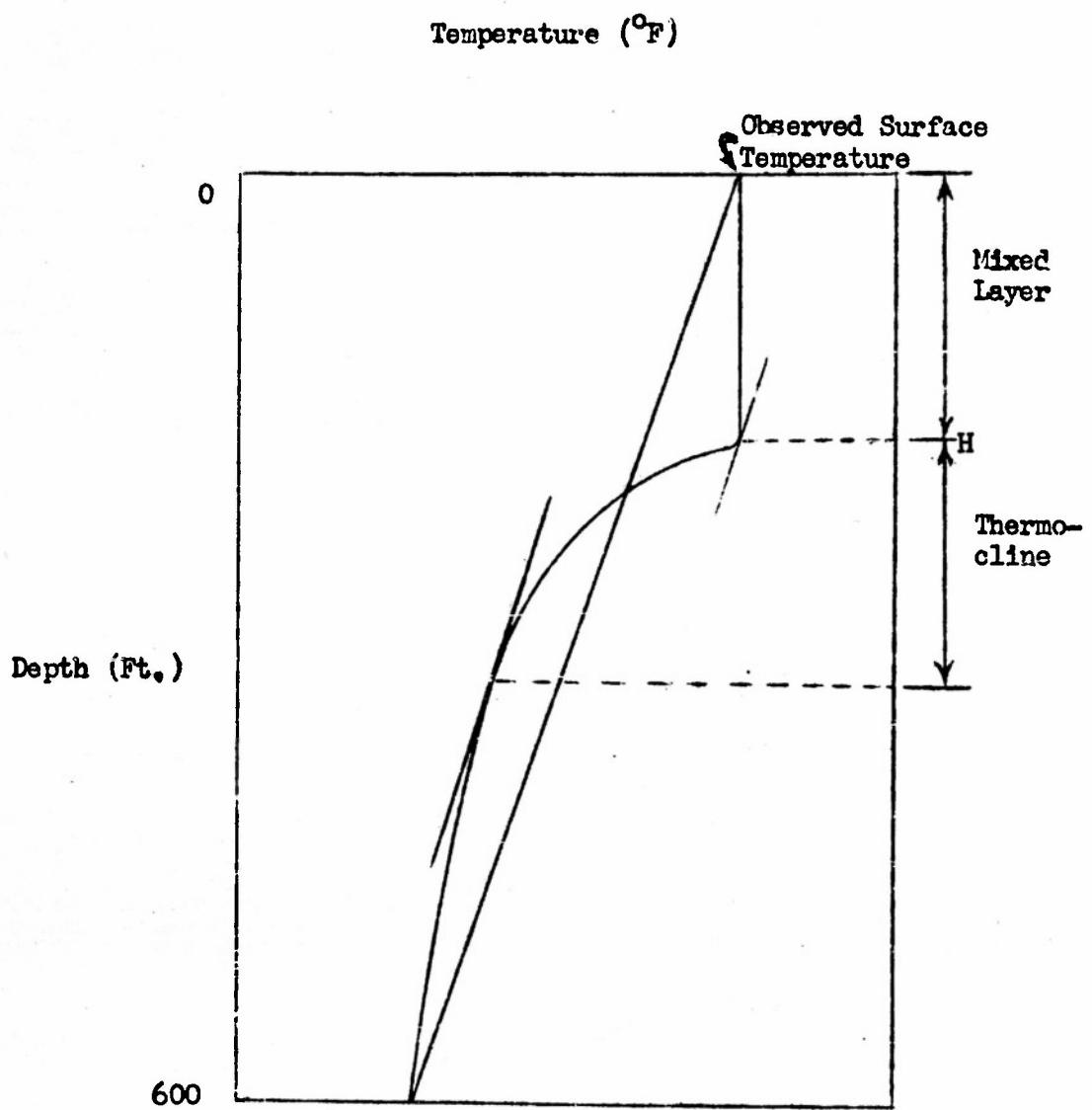
Figure 1

Otherwise particles in the upper layer might become more dense than those below, and convection would be initiated. This possibility is neglected in the following parts of this section.

If there is lateral variation in heating or cooling, horizontal motion is initiated by the expansion or contraction of the volume as compared with others at its level. Lateral variations in A_S, A_B and A_E are assumed to be small, and the volume changes due to heating are neglected.

Then if h is a level surface below which heat does not penetrate, say 600 feet,

$$(2) \quad \int_0^h \frac{\partial Q}{\partial t} \, dz \equiv A_T = A_S + A_B + A_E$$

The term, A_T, is the total heat added and has the units $\left[\dfrac{ft\text{-}deg.}{L^2 \, week}\right]$

Now assume that a lateral motion occurs. Then

$$(3) \quad A_T = - \int_0^h \left[u \frac{\partial Q}{\partial x} + v \frac{\partial Q}{\partial y} \right] + A_S + A_B + A_E \ ,$$

where u, v are the components of velocity and $Q = Q \, (x, \, y, \, z, \, t)$.

B. Heat Change in the Mixed Layer

The quantity, Q, is independent of depth in the mixed layer. Let (HQ) be the heat-content of a unit column of water in the mixed layer. Then, if A_M is the heat-change in the mixed layer,

$$(4) \quad A_M \equiv \frac{\partial \, (HQ)}{\partial t} = H \frac{\partial Q}{\partial t} + Q \frac{\partial H}{\partial t}$$

If some space-variation of H exists initially, and the system moves without change of form,

$$(5) \quad \frac{\partial H}{\partial t} = - \left[U_H \frac{\partial H}{\partial x} + V_H \frac{\partial H}{\partial y} \right] \ .$$

Change of form can result from the incorporation of water from below into the mixed layer. This has the combined effect of lowering the temperature of the upper layer and increasing its depth. Since these two influences tend to cancel each other in an evaluation of A_M, they are

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neglected in further discussion here.* But a local cooling of the mixed

layer by this means will result in horizontal motion. Neglecting other

affects of the wind, Dr. John Freeman has analyzed this possibility in

Technical Report No. 6.

Other changes in the form of the H-surface are induced by winds and

atmospheric pressure gradients. If the wind is always uniform in a direc-

tion perpendicular to its motion, assuming that water transport in the

mixed layer is 90° to the wind, there will be no change of form and pure

advection as represented by equation (5) results. But if not--i.e., if

the curl of the wind stress is not zero--there will be associated altera-

tions in H. Assuming that this influence is not reflected in a change in

level of the air-sea interface, Dr. John Freeman has related $\frac{\partial H}{\partial t}$ and the

wind-stress curl as follows:

$$(6) \quad \frac{\partial H}{\partial t} = \frac{1}{\rho f} \left(\frac{\partial \tau x}{\partial y} - \frac{\partial \tau y}{\partial x} \right).$$

where $\rho \equiv$ water density, $f \equiv$ coriolis parameter ($2 \omega \sin \phi$),

τx, $\tau y \equiv$ components of wind-stress. This study is reported in Technical

Report No. 5.

There is an effect due to any atmospheric pressure gradient over the

region in question which adds to equation (6). The influences of the wind

given by equations (5) and (6) are not independent, being related through

continuity considerations.

Now assume that all appreciable motion and heat change is confined to

a mixed layer that varies in thickness:

$$(7) \quad A_M = A_T = - \left[T_x \frac{\partial Q}{\partial x} + T_y \frac{\partial Q}{\partial y} \right] + A_S + A_B + A_E + Q \frac{\partial H}{\partial t} ,$$

where T_x, T_y are the components of volume transport in the mixed layer.

* See next section

Further assuming that advection of heat (the term in brackets in (7)) is negligible and that H changes primarily as a result of the wind-stress curl, Mr. G. H. Jung and Mr. R. A. Gilcrest based a heat budget study for one location in the North Atlantic Ocean on the equation

$$A_T = A_S + A_B + A_E + \frac{(\Theta_H - \Theta_{600'})}{\rho f} \left[\frac{\partial \tau_x}{\partial y} - \frac{\partial \tau_y}{\partial x} \right]$$

where Θ is the temperature. This is reported in Technical Report No. 4. A conclusion is that advection must be important at this location.

A study of the influence of advection is now under way. The basic equation employed is

$$A_T = - \left[T_x \frac{\partial \Theta}{\partial x} + T_y \frac{\partial \Theta}{\partial y} \right].$$

The situation is visualized as follows. All transport is due to the wind and takes place, throughout, but not below, the mixed layer. There may be a space variation in H but because at H there is no motion, no local change in H occurs. Under these conditions the water transport and the wind are connected by the equations

$$T_x = \frac{1}{\rho f} \tau_y , \qquad T_y = - \frac{1}{\rho f} \tau_x.$$

The results of this study will be reported later.

The Affect of Convection and Changing Turbulence on the Mixed Layer

The effects on Θ and H as they are imagined to occur when convection is initiated or the wind changes in magnitude, are qualitatively noted below.

Assume that the mixed layer is strongly turbulent throughout. Particles cooled at the surface, by evaporation principally, cannot descend to their proper density level. They are held in the eddies of the mixed layer until, by conduction, they cool their neighbors slightly and are

warmed until the mixed layer is again homogeneous. Thus Θ is decreased with a slight increase in H.

Another possible effect of convection is associated with weak turbulence in the mixed layer. The cooled particles descend into the thermocline, lessening H without change in Θ.

If a wind which has been blowing long enough to have developed a steady-state mixed layer, suddenly decreases in magnitude, eddies just above H will become smaller, approaching the size of eddies within the strongly stable thermocline. Their effect will be to decrease the gradient below H and to create a gradient above. Thus H is decreased without change in the mixed layer temperature.

If the wind strengthens, the mixed layer deepens, incorporating cooler water. Thus the temperature of the mixed layer decreases.

Development of certain consequences of these lines of thought is given in Technical Report No. 8 of this project. Using the temperature difference between air and water as an indication of air stability, a chart of stability vs. air speed was constructed. Qualitatively making use of the concepts above, smoothed lines of equal $\dfrac{\Delta H}{\Delta t} \left[\dfrac{ft.}{week} \right]$ were drawn on the chart. The result was checked for worth as a forecasting tool and found to give better than chance results. However, it would be difficult to make areal application of this approach using available data.

Instantaneous Space-Variations in the Mixed Layer Depth

Observations of surface temperature are far more numerous and more closely spaced than are BT observations. In an effort to obtain a reasonably good idea of instantaneous space-variations in H, use of the more abundant surface data is being made. Attention has been restricted, thus far, to data gathered in the North Atlantic during the Autumn.

Average monthly values of H and Θ_s, the surface temperature, are available in mapped form.* On the basis of these, graphs of H vs. Θ_s have been plotted for each 5° square in the North Atlantic. One point exists on each graph for each fall month. Then by plotting on a map of the North Atlantic all values of Θ_s actually observed during a given week, a corresponding pattern of H is obtained. It is hoped that by altering the pattern subjectively in accordance with the comparatively few observed values of H available, a good approximation of the average space-variation of H for the week will result.

This work is currently in progress and is being carried out by Mr. Gilcrest.

Ocean-Wide Heat Transport

The climatological study discussed below is based on data obtained by hydrographic casts. All other investigations conducted by this project have been based on BT observations which date only from World War II and do not reach deep enough into the sea to satisfy the need here.

It is postulated that an effective energy transport mechanism operates within the ocean in the form of vertical circulations operating along the meridians, perpendicular to latitude circles. Such circulations would have a rotation such that the upper portion would be directed poleward, on the average, while the deeper portion would be directed equatorward. Such a circulation, when operating in an ocean area possessing the usual temperature decline with increased depth, would transfer a net amount of heat poleward in its operation. Such poleward heat transfer would supplement that amount carried poleward by the motion of the atmosphere. It thus would

* "Monthly Sonar Conditions - North Atlantic Ocean and Mediterrean Sea" (Confidential), Hydro. Office Publication No.761, 1951 and "World Atlas of Sea Surface Temperature", Hydro. Office Publication No. 225, 2nd edition, 1944.

aid in maintaining the radiation balance of the earth's envelope. In the upper ocean layers the effects of such circulations would probably be classed as advection as far as the heat budget of local ocean columns are concerned.

It may be shown that the magnitude of energy transported by such vertical meridional cells within the ocean is given by the term for transport of internal energy alone:

$$\int_A C_p \, K\rho v_n \, dA$$

C_p is the specific heat of ocean water at constant pressure; K is absolute temperature; ρ is density _in situ_; v_n is the poleward component of velocity; A is the area of the cross section over which the energy is integrated.

On this contract, work nearly has been completed in evaluating this internal energy transport term across two vertical sections through the North Atlantic Ocean. These results, at 0° and $45^{\circ}N$, when added to those previously obtained for $27^{\circ}N$, will allow estimates of the divergence of heat transport and estimates of the ocean energy balance to be made between the latitude bands.

Tentative results for $0-27^{\circ}N$ agree with expectations from quantitative atmospheric data and radiation balance requirements. Future work planned includes the analysis of five additional sections across the North Atlantic Ocean, making a systematic pattern of investigated sections from the equator to 63 deg. N. Lat.

In Conclusion

Having knowledge of the heat distribution in the sea at a given time, the practical aim of these studies is to be able to predict the distribution

at a later time. A reasonably good concept of month-to-month changes in
the thermal structure has been had for some time. This project has dealt,
primarily, with week-to-week changes. As larger quantities of intensive
data become available, day-to-day changes will be studied.

Aside from the interest in the thermal structure problem as such,
there is the very significant affect that the distribution of heat has on
sound transmission in the sea. It is planned during the course of the next
year to devote more time to relating directly the meteorological variables
to their affects on the transmission of sound. Information gained in
thermal structure studies will be used.

Work along the lines laid out in the body of this paper will continue
under Contract N7onr-487, T. O. 2. There is good evidence that the studies
of advection now under way will lead to results of practical significance.

STAFF AND STAFF CHANGES

At the close of the period covered by this report the staff of Project 29 was as follows:

1. Dr. Dale F. Leipper, Project Supervisor (Part time)
2. Mr. Glenn H. Jung, Chief Scientist
3. Dr. John C. Freeman, Meteorologist (Part time)
4. Mr. Robert A. Gilcrest, Assistant in Oceanography
5. Mr. Carter R. Sparger, Assistant in Oceanography
6. Mr. William G. Bradley, Research Assistant (Part time)
7. Mrs. Jeanneane L. Cline, Secretary-Computer
8. Mrs. Bertha Darrow, Secretary-Computer (Part time)
9. Mrs. Margaret S. Holdredge, Computer (Part time)
10. Mrs. Roberta S. Eidemiller, Draftsman (Part time)

Mr. Archie M. Kahan, formerly Chief Scientist, left the project 31 July 1953 to become Assistant to the Head of the Department in Research. Mrs. Marilyn C. Johnson, Computer (Part time), resigned 20 January 1954. Mrs. Jacklin M. Hudson was employed on 4 April 1954 as Secretary-Computer. She resigned on 18 April 1954.

In addition to the above changes in the permanent staff the following listed temporary employees worked during the periods listed:

1. Mr. U. G. Whitehouse, Oceanographer, 1 June 1953 - 30 June 1953
2. Mrs. Barbara Creager, Draftsman, $3\frac{1}{2}$ days during July 1953
3. Mr. William A. Price, III, Shop worker (Part time), January 1953
4. Charles E. Griffin, Student Assistant, 1 Feb. 1954 - 30 April 1954

TECHNICAL REPORTS

No. 1 Some Methods Used in Representing Bathythermograph Data; Dale F. Leipper and Richard M. Adams; May 1952.

No. 2 Deviations of Mixed Layer Depth and Sea Surface Temperature in Different Years in the North Atlantic; Robert A. Gilcrest and Dale F. Leipper; July 1952.

No. 3 Summary of North Atlantic Weather Station Bathythermograph Data (1946-1950); Dale F. Leipper, Richard M. Adams and Project Staff; September 1952.

No. 4 Heat Budget of a Water Column, Autumn - North Atlantic Ocean; Glen H. Jung and Robert A. Gilcrest; July 1953.

No. 5 Note on a Prediction Equation for the Surface Layer of a Two Layer Ocean; John C. Freeman, Jr.; June 1953

No. 6 Wind Mixing Currents; John C. Freeman, Jr.; October 1953.

No. 7 Summary of North Pacific Weather Station Bathythermograph Data; Dale F. Leipper and Project Staff; January 1954.

No. 8 Empirical Relations between the Weather and the Ocean Mixed Layer; Robert A. Gilcrest, Glenn H. Jung and John C. Freeman, Jr.; March 1954.

Full Name	FREEMAN, JOHN C., JR.
Born	Houston, Texas, 1920

Training	The Rice Institute, Houston, Texas, 1937-41, B.A.
	    Major - mathematics; minor - physics
	The California Institute of Technology, 1941-42, M.S.
	    Major - meteorology
	Brown University, Rhode Island, 1946-48
	    Major - applied mathematics
	University of Chicago, Illinois, 1950-52, Ph.D.
	    Major - meteorology

Experience	U. S. Army Air Force 1941-46, weather officer, forecasting
	    and research in the Caribbean, Southern United States,
	    New Guinea, and the Master Analysis Center in Washington.
	Brown University, Providence, Rhode Island, 1946-48,
	    research in fluid dynamics
	The United States Weather Bureau, Washington, D. C., 1948,
	    research in meteorology
	The Institute for Advanced Study, Princeton, New Jersey,
	    1949-50, research in theoretical meteorology
	The University of Chicago, Chicago, Illinois, 1950-52,
	    research in meteorology
	Texas A. & M. College, Department of Oceanography, 1952-
	    1953, Assistant Oceanographer (meteorological), research
	    in meteorology and oceanography
	Texas A. & M. College, Department of Oceanography, 1953-
	    Assistant Professor

Organizations	Sigma Xi American Meteorological Society American Mathematical Society

Awards	Received the Meisinger Award for 1951 from the American
	    Meteorological Society jointly with Morris Tepper for
	    work in hydraulic analogies to meteorological phenomena.

Publications	"Stability of Boundary Layers and Flow at the Entrance
	    Section of a Channel", Hahneman, Freeman, Finston,
	    Journal Aeronautical Sciences, Vol. 15, No. 8, 1948.
	Stability of the Boundary Layer, P. Chiarulli & J. C.
	    Freeman, Graduate Division of Applied Mathematics, 1948.
	"An Analogy Between the Equatorial Easterlies and Supersonic
	    Gas Flows", J. Meteor., 5:138-146 (1948)
	"Reply: The Usefulness of Incompressible Models", J. Meteor.,
	    6:287 (1949)
	"Map Analysis in the Vicinity of a Pressure Jump", Bull.
	    Amer. Meteor. Soc. 31, 324-325 (1950)

Freeman, John C., Jr. (Continued)

Publications
(Cont'd)

"The Wind Field of the Equatorial East Pacific as a
    Prandtl-Meyer Expansion", Bull. Amer. Meteor. Soc.
    31: 303-304 (1950)
"Analogy Between Equatorial and Supersonic Flows", Tepper
    & Freeman, J. Meteor 6: 226 (1949)
"Note on the Minimum Critical Reynolds Number and the
    Form Parameter", Journal of the Aeronautical Sciences
    Vol. 18, 16.5 (1951)
"The Method of Characteristics in Meteorology", Compendium
    of Meteorology, 1951.
"The Squall Line as an Internal Wave", Mimeographed Report,
    University of Chicago, 1951
"Dynamic Models of Radar Scope Patterns", Proceedings
    of the Third Radar Weather Conference, 1952
"Unitary Representation of Radar Cloud and Precipitation
    Data", Proceeding of the Third Radar Weather Conference,
    1952
"Inter-Relations Between Jet Behavior and Hydraulic
    Processes Observed at Detic River Mouths and Tidal
    Inlets", with Charles C. Bates, Proceeding of the
    Third Coastal Engineering Conference 1953.
"Radar Echoes in Tornado Situations," Proceedings of the
    Conference on Radio Meteorology, 1953.

To be published

"The Stability of the Boundary Layer Profile $u = 1 - e^{-y/\delta}$ *".
"A Meteorological Significant Marching Problem"
"Blocking as a Finite Disturbance of the Jet Stream"
"Dynamics of a Jet Stream Model"
"Flow Under an Inversion in Middle Latitudes". (Thesis,
    University of Chicago)
"Note on a Prediction Equation for the Surface Layer of a
    two Layer Ocean"
"A Criterior for a Corner in a Vertical Temperature Trace"
"On Wind Induced Water Level Changes: Finite Amptitude of
    Long Wave Length"
"Wind Mixing Currents"
"Vorticity on the Weather Map"
"Radar Networks"
"Flow of a Jet into a Wall"

May 1, 1954

Full Name	GILCREST, ROBERT ALLEN
Born	Hartville, Ohio, 16 July 1916
Training	Mount Union College, Alliance, Ohio, 1938, B.S. Major – Biology and Chemistry
	Chanute Field Forecaster's School, Rantoul, Illinois, 1942 (left to become cadet)
	Massachusetts Institute of Technology, 1943, Certificate in Meteorology, 1951, two semesters of graduate work in meteorology
	Texas A. & M. College, Department of Oceanography, 1952-date, graduate student in physical and meteorological oceanography.
Experience	Actor in State of Ohio historical pageant and trek, 1938.
	Hartville, Ohio, 1939-41, farmer and vegetable grower
	U. S. Medical Corps, 1941, surgical technician
	Transferred to Air Corps, 1942
	MacDill Field, Tampa, Florida, 1942, in-station observer training and five months observer duty; discharged from U. S. Army Air Corps following commission as Weather Officer, December 1943.
	Eastern Air Lines, La Guardia, New York, 1943-46, domestic air line forecasting and traffic forecasting.
	U. S. Weather Bureau, Keflavik, Iceland, 1946-47, ocean weather forecasting and observation supervision for Air Transport Command and commercial operations
	American Overseas Air Lines, Stockholm, Sweden and Shannon Airport, Ireland, 1947-51, worked with Swedish and Irish Meteorologists forecasting ocean weather and winds (cross-sections along routes across North Atlantic), terminal forecasting; helped maintain historical surface map series
	Texas A. & M. Research Foundation, Associate in Oceanography (meteorological), 1951 to date – research work on the atmospheric influence on the thermal structure of the oceans and on the wind field near the tropopause.
Organizations	College: Alembroic – honorary chemistry society
	Phi Sigma – honorary biology society
	Professional: American Meteorological Society
	American Geophysical Union
Publications	"Heat Budget of a Water Column Autumn – North Atlantic Ocean", Glenn H. Jung and Robert A. Gilcrest, Submitted to the Journal of Meteorology.

May 1, 1954

Full Name	JUNG, GLENN HAROLD
Born	Lyons, Kansas, 11 October 1924
Training	Colorado State College of Education, 1941-43, Major: Mathematics.
	Massachusetts Institute of Technology 1943-44, Major: Meteorology, Completed Army Cadet Course.
	Massachusetts Institute of Technology 1947-49, Major: Meteorology, SB, Jan. 1949.
	Massachusetts Institute of Technology 1949-52, Major: Meteorology, SM, Jan. 1952.
	Texas A. & M. College, 1952-1954, Ph.D. Candidate in Physical Oceanography.
	University of Oslo, Norway, 1954- Major: Oceanography.
Experience	Weather Officer, Air Force 1944-47.
	Research Assistant MIT, Dept. of Meteorology 1950-51.
	DIC Staff Member, MIT, Dept. of Meteorology, 1952.
	Research Assistant Texas A. & M. College, Dept. of Oceanography, 1952-53.
	Associate in Oceanography and Acting Assistant Professor of Physical Oceanography, 1953-1954.
Organizations	American Meteorological Society, Professional Member
	Sigma Xi, Associate Member, Texas A. & M. Chapter.
Awards	Granted Fulbright Award for Advanced Study in Oceanography at the University of Oslo, Norway, July 1954, August 1955.
Publications	Large-scale Atmospheric Exchange Processes As Diffusion Phenomena, co-author, Journal of Meteorology, 8 (5) 1951.
	A Note on the Energy Transported by Ocean Currents, Journal of Marine Research, 11, (2), 1952.
	Heat Budget Study - Autumn - North Atlantic Ocean, Senior author, submitted to Journal of Meteorology.

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